HP TURBINE UPGRADE PROJECT

PROCEDURE FOR

HP TURBINE EFFICIENCY TEST

INTRODUCTION

turbine

This procedure defines the HP ~~cylinder~~ efficiency test that will be undertaken to demonstrate that the guarantee performance requirements of the Contract have been met. The tests will be carried out by NORTHERN STATES POWER COMPANY (NSP) and witnessed by ALSTOM POWER. NSP will supply and install test instrumentation to the requirements of ASME PTC 6.

The test will be carried out in accordance with the contract and ASME PTC 6: 1996 "Performance Test Code on Steam Turbines", except as otherwise mutually agreed between NSP and ALSTOM.

1 OBJECTIVE OF TESTS

steam flow passing capability

The objective of the test is to measure the HP turbine efficiency and steam swallowing capacity, following installation of the upgraded HP turbine.

and HP turbine power

2 CONTRACTUAL GUARANTEE

2.1 The HP turbine section upgrades provided by ALSTOM are guaranteed to provide the following HP turbine efficiencies (main steam valve inlet to HP turbine exhaust) when operating the turbine with all nozzle control valves wide open, at the new rated steam conditions:

X % guaranteed HP turbine efficiency for the upgrade designed for a 3+1 valve sequence. This value includes the effect of the indicated HP valve pressure drop at two point nine percent (2.9%).

For information purposes, the expected HP section efficiency at the same conditions but excluding valves is Y %.

2.2 ALSTOM guarantees that the swallowing capacity of the HP turbine at the specified conditions will be Z lb/hr.

3 SCOPE OF TESTS

3.1 Guarantee Tests

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The HP cylinder efficiency achieved from the blading upgrade will be verified by an enthalpy drop test. This test will be conducted as soon as practicable after steam is readmitted to the unit; this should not be more than 8 weeks after the unit is re-synchronized. During the tests the unit will operate as close as possible to the normal maximum operation conditions with all the nozzle control valves wide open.

The results of the tests will be corrected (as appropriate) for any significant variations of the relevant terminal conditions from those specified, using correction factors agreed in advance of the tests, before comparison with guarantees.

The HP turbine steam swallowing capacity will be calculated from the main steam flow at inlet to the turbine stop valves, derived from measurements using the condensate flow section. Heat balances will be calculated around the HP heaters and the deaerator to determine the flow to the boiler and hence steam flow to the turbine stop valve.

3.2 Benchmark Tests

Benchmark enthalpy drop tests will be taken periodically from the time of initial loading of the turbine and the results recorded for reference purposes.

4 TEST PREPARATION

4.1 Plant Operation and Control

Before starting the performance tests on the turbine generator unit, all relevant plant automatic control systems are to be set and working effectively to achieve the required values and stability of the operating steam conditions.

All feed water heaters will be in service and operating normally.

Sliding pressure operation

4.2 Work Carried Out during Replant Outage

During the outage NSP will check all relevant instrument tappings and make sure that they are suitable for use during the tests.

Pressure tapping points, which have been capped off, will need to be re-instated and piped down to convenient location. Any new pressure tappings, such as pressure at HP turbine inlet, will need to be installed during the outage.

The bore of thermowells will be checked for blockage and cleaned if necessary.

5 TEST INSTRUMENTATION

Appendix I contains the test instrument list. NSP will supply and install test instruments, of the accuracy called for in the test code.

5.2 Pressure Measurement

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Calibrated 0.1% accuracy pressure transducers will measure all static pressures. All measured pressures will be corrected for the static water leg and, where appropriate, atmospheric pressure.

Atmospheric pressure will be measured using a precision barometer.

5.3 Temperature Measurements

All temperatures will be measured using calibrated platinum resistance thermometers located in thermometer wells.

5.4 Flow Measurement

The initial assessment of the steam swallowing capacity of the steam turbine will be made by measuring the condensate flowrate using the currently installed condensate flow nozzle section. This flow section will not be calibrated or changed prior to any of the testing. If the initial assessment of the steam swallowing capacity suggests that the guaranteed value has not been achieved within the specified tolerance, then the currently installed condensate flow nozzle section will be replaced with a calibrated flow nozzle section, and the steam swallowing capacity of the steam turbine will be re-measured.

NSP will bear all costs associated with supplying and fitting of the new calibrated flow section, unless the re-test confirms that the steam swallowing capacity is outside the specified tolerances. In this event ALSTOM will bear all costs associated with supplying and fitting the new calibrated section.

The flow will also be calculated using the recently installed feedwater flowmeter as a crosscheck against the flowrate derived from the condensate flow section. This flow will also be taken into account before deciding to install the new calibrated flow section.

The differential pressure across the condensate and feedwater flow nozzles will be measured by duplicate 0.1% calibrated differential pressure transducers. All other subsidiary flowmeters will be measured by single 0.1% calibrated differential pressure transducers.

5.5 Data Acquisition System

All output signals from pressure transducers and resistance thermometers will be recorded automatically using a computer controlled data acquisition system.

6   CALIBRATION OF TEST INSTRUMENTATION

NSP will calibrate all instruments before the tests, using transfer standards traceable to National Standards. Re-calibration following the test, will only take place where Alstom and NSP agree the requirement is necessary.

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7   TEST PROCEDURE

7.1 Plant Operation and Safety

NSP will appoint a 'Test Controller' to co-ordinate the running of the plant, to arrange satisfactory conditions for of each test, and to liaise with all the test engineers.

The operations staff will take any action needed to maintain safety during the course of a test. The Test Controller will immediately advise the test engineers of any changes to the operating conditions or plant isolation. NSP and ALSTOM will then agree whether to continue or abandon the test.

7.2 Valve Isolation List

NSP will produce a valve isolation list so the all valves requiring closure during the test can be tagged , and checked for correct closure during the test.

7.3 Number and Duration of Tests

Two VWO (valves wide-open) performance tests, each of a nominal 1 hour duration will be carried out. The tests will be compared for repeatability and repeat tests carried out if the results are inconsistent.

7.4 Frequency of Readings

Pressure and temperature readings will be automatically logged at intervals no greater than 1 minute.

7.5 Terminal Conditions

The HP turbine efficiency will not vary significantly over a wide range of inlet pressures and temperatures. However, for test accuracy reasons, it is essential that the performance tests be conducted with all of the control valves in the fully open position. Terminal conditions must also be held steady as near to the proposed test values as possible for at least 1 hour before the start of the test. Further, the maximum permissible fluctuation of the inlet conditions from the mean during any one test run, as allowed by ASME PTC 6: 1996 are: -

Variable	Maximum Permissible Fluctuation From Test Average
Steam pressure before HP stop valve	±0.25% of absolute pressure
Steam temperature before HP stop valve	±7 °F

Note: By mutual agreement between all parties involved, it is acceptable to conduct tests with deviations outside the limit set out in the table.

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8   CALCULATION OF RESULTS

8.1 HP Turbine Efficiency

The detailed calculation methods for the various tests are shown on the calculation sheets in Appendix II of this procedure.

The HP cylinder efficiency is defined as follows:

$$HP\,efficiency = \frac{h_1 - h_2}{h_1 - h_2'}$$

Where, h_1 =   steam enthalpy before HP turbine stop valves

h_2 =   steam enthalpy at HP exhaust

h_2' =   steam enthalpy at HP exhaust assuming isentropic expansion from before the main steam valves

8.2 Steam Swallowing Capacity

The mass throttle flowrate will be derived from the measured condensate flowrate by taking into consideration the steam flowrate to the HP heaters and deaerator, and also any secondary flows such as spraywater, auxiliary steam and known boiler losses.

The calculated steam swallowing capacity will be corrected to the design steam inlet conditions of 2460 psig and 1000 ° F. The average of the two VWO tests will used to calculate the test results for comparison with the guarantee based on the equation below:

$$m_{1corr} = m_{1test} \times \frac{\sqrt{(p_{design} \times \upsilon_{test})}}{\sqrt{(p_{test} \times \upsilon_{design})}}$$

Where m_{1corr} = mass flowrate at turbine stop valve corrected to design steam inlet conditions (lb/h)

m_{1test} = test mass flowrate at turbine stop valve (lb/h)

p_{test} = test steam pressure at TSV (psia)

p_{design} = design steam pressure at TSV (psia)

υ_{test} = test steam specific volume at TSV (ft ^{3}/lb)

υ_{design} =design steam specific volume at TSV (ft ^{3}/lb)

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8.3 Test Tolerances and Allowances

8.3.1 Measurement Uncertainty

HP Turbine Efficiency

HP turbine efficiency is derived from measurements of associated pressures and temperatures which are subject to measurement uncertainty.

Tolerances for measurement uncertainty applied to the efficiency test results shall be calculated using the actual test instrument uncertainties and shall not exceed 0.5%

HP Turbine Swallowing Capacity

The steam swallowing capacity shall be between the limits of:

8.3.2 Excessive Deterioration

ASME PTC 6 Report-1985 gives guidance in clauses 3.06 and 3.07 on the average expected performance deterioration cause by delayed tests. An additional allowance will apply to the guarantee test result if the benchmark tests show that the deterioration between initial steaming and the guarantee test is excessive. This allowance will equal the difference between the measured deterioration and the ASME guidance norm and will be added arithmetically to the tolerance for measurement uncertainty. For this turbine configuration , the HP turbine is taken to account for approximately 50% of the total degredation.

8.3.3 Delayed Testing

If the tests are delayed beyond the recommended 8 weeks after re-synchronisation, a deterioration allowance equal to the ASME guidance norm will be applied to the results. This allowance will be added arithmetically to the tolerance for measurement uncertainty. For this turbine configuration, the HP turbine is taken to account for approximately 50% of the total degredation.

8.3.4 Steam Tables

The 1967 steam tables will be used in the calculation of the test results.

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APPENDIX 1

Schedule of Readings and Instrumentation

The following abbreviations are used to describe the type of instrument required in this schedule :-

PT	Pressure transducer
B	Barometer
PRT	Platinum resistance thermometer
DPT	Differential Pressure Transducer

ASME Table

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APPENDIX 2

Calculations

POWER PLANT UNIT 1

Test No.   Date: .

Nominal Load   MW   Test Period: .

Turbine

CALCULATION OF HP ~~CYLINDER~~ EFFICIENCY

	Pressure	Temperature	Enthalpy	Entropy
	psia	°F	Btu/lb	Btu/lb °R
Steam before HP stop valve			h_1	
Steam at HP cylinder inlet				
Steam at HP exhaust			h_2	
Steam at isentropic point			h_2'	

HP Turbine Efficiency $= \dfrac{(h_1 - h_2)}{(h_1 - h_2')} \times 100\%$

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